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Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia

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ABSTRACT

This study examines the linkages among economic growth, energy consumption, financial development, trade openness and CO_2 emissions over the period of $1975Q_1$–$2011Q_4$ in case of Indonesia. The stationary analysis is performed by using Zivot–Andrews unit root test and the ARDL bounds testing approach for a long run relationship between the series in the presence of structural breaks. The causality between the concerned variables is examined by the VECM Granger causality technique and robustness of causal analysis is tested by innovative accounting approach (IAA).

Our results confirm that the variables are cointegrated; it means that the long run relationship exists in the presence of structural breaks. The empirical findings indicate that economic growth and energy consumption increase CO_2 emissions, while financial development and trade openness compact it. The VECM causality analysis has shown the feedback hypothesis between energy consumption and CO_2 emissions. Economic growth and CO_2 emissions are also interrelated i.e. bidirectional causality. Financial development Granger causes CO_2 emissions. The study opens up new policy insights to control the environment from degradation by using energy efficient technologies. Financial development and trade openness can also play their role in improving the environmental quality.

Contents

1. Introduction

The international trend indicates that various countries have resisted in attaining economic growth exclusive of parallel observing a boost in CO_2 emissions. On the other hand, there has been rising apprehension over the technique of 'low carbon and green growth'. Specifically, the inquiry of whether it truly is feasible to reach constant

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economic growth not including growing energy consumption or greenhouse gases has circled into a topic of particular consideration. Developing and underdeveloped countries have disagreed that some constraints on carbon energy would hinder economic expansion and recommended that industrial countries should increase funds to alleviate global warming, which is extensively measured as a result of emissions by industrial countries. This issue is moderately connected to post-Kyoto discussions over climate change, and therefore, it is vital to observe the association between environment and economic growth by using empirical analysis tools.

Indonesia declared independence after the surrender of Japanese on 17 August 1945. The population growth rate is 1.03 per cent, 17.7 births/1000 with 6.3 deaths/1000 and 44 per cent of total population is living in urban areas in 2012. The real GDP growth rate is 6 per cent and sectoral growth is 14.3 per cent in agriculture, 46.9 per cent in industry and 38.8 per cent in services is recorded in 2012 as well as investment as share of GDP is 33.6 per cent. The decline in lending rate from 12.95 in 2011 to 11.3 per cent in 2012 by commercial banking sector increased domestic credit to private sector. The reforms in financial sector increased the confidence of foreigners and foreign direct investment raised from $40.47 billions in 2011 to $48.57 billions in 2012. Although, exports has declining trend in 2012 ($201.5 billions in 2011 but in 2012 exports are $ 199.1 billions) and imports have been increased from $166.1 billions in 2011 to $185 billions in 2012. The volume of energy consumption (kg of oil equivalent per capita) in Indonesia in 2010 was 866.50. Indonesia's CO_2 emissions increased from 0.40 metric tons per capita in 1975 to 1.89 metric tons per capita in 2010. Energy consumption and CO_2 emissions have increasing trends in recent years. Recently, the Indonesian government has begun to pay attention to the growth of green policies. The president Susilo Bambang Yudhoyono approved the reduction of Indonesia's CO_2 emissions by 26 per cent against a business as usual (BAU) trajectory in 2020, the largest absolute reduction commitment made by any developing country. Contingent on the availability of international financial support, the president also committed Indonesia to a 41 per cent reduction in greenhouse gas emissions.

In recent times, a few readings have investigated the causal association among energy consumption, CO_2 emissions, and economic growth. Though, these empirical investigations have shown mixed results, which calls for additional study to elucidate this association. Incidentally, the current investigation gives an empirical analysis of this multivariate Ganger causality affiliation by considering the case of Indonesia. Indonesia is the fourth largest populous country on the earth. The main energy consumption in Indonesia increases 50 per cent in the period of 2000–2011. The current study probes the association among economic growth, energy consumption, financial development, trade openness and CO_2 emissions using the quarter frequency data of the Indonesian economy over the period of 1975–2011. This is a main motivation for researchers. Due to our imperfect knowledge, this study may be a comprehensive effort on this topic for the economy of Indonesia and it has five fold contributions to the energy literature by applying: (i) Zivot–Andrews [1] structural break unit root test; (ii) the ARDL bounds testing approach to cointegration for long run relationship between the variables in the presence of structural breaks; (iii) OLS and ECM for long run and short run impacts; (iv) the VECM Granger causality approach for causal relationship and (v) Innovative Accounting Approach (IAA) to test the robustness of causality analysis.

Our empirical findings show that cointegration is found among the variables such as economic growth, energy consumption, financial development, trade openness and CO_2 emissions in case of Indonesia. A rise in energy consumption, economic growth, financial development (trade openness) increases (condenses) CO_2 emissions. The causality analysis reveals that the bidirectional causal relationship is found between energy consumption and CO_2 emissions. Financial development Granger causes CO_2 emissions, economic growth and trade openness. The feedback hypothesis is validated between trade openness and CO_2 emissions and, the same inference is drawn between economic growth and energy consumption. Bidirectional causality is found between trade openness and energy consumption while economic growth is cause of trade openness. These results may provide new avenues for policy makers to design a comprehensive economic, financial, trade and environmental policy to sustain economic growth in Indonesia.

2. Literature review

The first strand of existing energy literature deals with a wide range of mixed result studies about energy consumption and economic growth nexus. Now a days, energy–growth relation has been empirically investigated extensively since the original study accomplished by Kraft and Kraft [2]. The empirical findings of the existing energy literature are not unambiguous due to the use of various econometric approaches such as correlation analysis, simple regressions, bivariate causality, unit root tests, multivariate cointegration, panel cointegration, vector error correction modeling (VECM) and innovative accounting approach to detect the direction of causality between economic growth and energy consumption (Chontanawat et al. [3]; Shahbaz and Lean [4]). These inconclusive empirical evidences could not help economic policy planners in lucid a wide-ranging energy plan to prolong long run economic growth (Ozturk and Acaravci [5]; Payne [6]) With the appropriate knowledge about the direction of causality between energy consumption and economic growth is very essential regarding theoretical and policy point of view (Ghali and El-Sakka [7]).

In recent studies, Payne [6] and Ozturk [8] reviewed the existing literature that linking energy consumption and economic growth nexus and provided four empirical competing hypotheses for said issue: (i) growth hypothesis i.e. energy consumption Granger causes economic growth implies that energy reduction policies should be discouraged and new sources of energy must be explored, (ii) if causality is running from economic growth to energy consumption then energy reduction policies would not have adverse effect on economic growth because economic growth of the country does not seem to be dependent on energy, and (iii) feedback hypothesis implies the interdependence of energy consumption and economic growth. A rise in economic growth leads to increase in energy demand, which in return stimulates economic growth. In such a situation, energy conservation policies are detrimental to economic growth and, (iv) no causality between energy consumption and economic growth infers neutrality hypothesis indicating that energy and growth are independent. The adoption of conservation and exploration of energy policies will not have a favorable effect on the economic growth. Furthermore, Yildirim et al. [9] also noted neutral effect between renewable energy consumption and economic growth in case of USA.[2]

The second strand of existing literature on this topic provides empirical evidence on the relationship between economic growth and CO_2 emissions i.e. so called environmental Kuznets curve (EKC). The EKC hypothesis postulates that the relationship between economic growth and CO_2 emissions is non-linear and inverted-U shaped. This implies that economic growth is linked with an increase in CO_2 emissions initially and declines it, once economy matures.[3] Existing

[2] Narayan and Prasad [10] and Shahbaz et al. [11] used electricity consumption as an indicator of energy consumption to examine the energy-growth nexus.

[3] At initial level of economic growth, a rise in income is linked with an increase in energy consumption that raises CO_2 emissions and hence environmental degradation. It implies that there is positive relationship between economic growth and CO_2 emissions at low level of income. After achieving certain level of income,

studies including Cropper and Griffiths [13], Grossman and Krueger [14], Hettige et al. [15], Martínez-Zarzoso and Bengochea-Morancho [16], and Selden and Song [17], among others investigated the relationship between income and emissions and validated the existence of the EKC But Dinda and Coondoo [18] used panel data and provided ambiguous results about economic growth and CO_2 emissions relationship. Recently, various studies validated the environmental Kuznets curve (EKC) using cross-sectional data, for instance, Lean and Smyth [19] for ASEAN; Ozturk and Acaravci [20] for Central America and commonwealth of independent states; Pao and Tsai [21] for BRIC countries; Pao et al. [22] for Russia; Wang [12] for 138 developing and developed countries, etc. But using time series data, Machado [23], Mongelli et al. [24], Ang [25,26], Song et al. [27], Jalil and Mahmud [28], Shiyi [29], Dhakal [30], Halicioglu [31], Ozturk and Acaravci [5][4] Alam et al. [33], Fodha and Zaghdoud [34], Nasir and Rehman [35], Shahbaz et al. [36], Shahbaz et al. [37], Tiwari et al. [38], and Kanjilal and Ghosh [39] also supported the empirical presence of the environmental Kuznets curve (EKC) for Brazil, Italy, France, Malaysia, China, India, Tunisia, Pakistan, Romania and India.

Third strand deals with country case studies, for example in case of United States, Soytas et al. [40] investigated the dynamic relationship between CO_2 emissions, income and energy consumption. Their results showed that CO_2 emissions Granger causes income and energy consumption contributes to CO_2 emissions. A similar exercise was conducted by Ang [25,26] in France and Malaysia. The results indicated that economic growth Granger causes energy consumption and carbon emissions in France and in Malaysia, unidirectional causality is found running from economic growth to energy consumption. Chebbi [41] collected the Tunisian data to investigate the causal relationship between energy consumption, income and CO_2 emissions. The empirical evidence indicated that energy consumption stimulates economic growth which Granger causes CO_2 emissions. In case of India, Ghosh [42] investigated the causal relationship between income and CO_2 emissions by incorporating investment and employment as additional determinants of CO_2 emissions but reported no causality between income and CO_2 emissions. Chang [43] applied multivariate causality test to examine the causal relation between economic growth, energy consumption and CO_2 emissions using Chinese data. The findings of the study revealed that economic growth Granger causes energy consumption that leads to CO_2 emissions. Using Turkish data, Halicioglu [31] also reported feedback hypothesis between economic growth and CO_2 emissions. In case of South Africa, Menyah and Wolde-Rufael [44] concluded that energy consumption Granger causes CO_2 emissions and resulting in economic growth is being Granger caused by CO_2 emissions. On contrary, Odhiambo [45] reinvestigated the causality between energy consumption, economic growth and CO_2 emissions and unidirectional causality also found running from economic growth to CO_2 emissions. Similarly, Alam et al. [46] examined the link between energy consumption, economic growth and energy pollutants in case of India. Their empirical evidence revealed the bidirectional causal relationship between energy consumption and CO_2 emissions while neutral hypothesis exists between CO_2 emissions and economic growth. In case of Bangladesh, Alam et al. [33] detected the causal relationship between these variables and opined that variables are cointegrated for the long run. These long run results are robust, confirmed by the ARDL bounds testing. Their VECM causality analysis reported the presence of feedback hypothesis between energy consumption and CO_2 emissions, while unidirectional causality is found running from CO_2 emissions to economic growth. In case of Greece, Hossain [47] applied the VECM Granger causality test to investigate the causality between energy intensity, income and CO_2 emissions by applying Johansen multivariate cointegration approach. Their results concluded the existence of long run relationship between the series. The VECM Granger causality analysis reported that unidirectional causality is found running from economic growth to energy intensity and CO_2 emissions, while feedback hypothesis exists between energy intensity and CO_2 emissions. In case of India, Alam et al. [46] examined causality between energy consumption, CO_2 emissions and economic growth and found that causality between CO_2 emissions and economic growth is independent. JaeHyun and TaeHoon [48] examined the relationship between energy consumption, economic growth and CO_2 emissions in case of Korea using Morkov switching model. They found long run relation between the variables and noted unidirectional causality economic growth to CO_2 emissions. Esteve and Tamarit [49] investigated the validation of EKC in Spain over the period of 1857–2007. They found that relationship between economic growth and CO_2 emissions is non-linear i.e. EKC exists. The empirical existence of EKC in Spain later on was rejected by Esteve and Tamarit [50].

The fourth strand deals with financial development and CO_2 emissions. For example, Tamazian et al. [51] paid their attention to test the effect of other potential determinants of CO_2 emissions such as economic, institutional, and financial variables. In their pioneering effort, Tamazian et al. [51] investigated the impact of economic development as well as financial development on CO_2 emissions in case of Brazil, Russia, India, China, Untied States and Japan and later on Tamazian and Rao [52] examined the role of institutions on CO_2 emissions. Their empirical evidence reported that economic development, trade openness, financial development and institutions play their role to control the environment from degradation while supporting the presence of EKC hypothesis. In case of China, Yuxiang and Chen [53] argued that financial sector polices enables the firms to utilize advanced technology which emits less CO_2 emissions and enhances domestic production. They also claim that financial development promotes capitalization and financial regulations that favor environmental quality. Later on, Jalil and Feridun [54] tested the impact of economic growth, energy consumption and financial development on carbon emissions in case of China. They disclosed that energy consumption, economic growth and trade openness are harmful for environmental quality. On the contrary, financial development and foreign direct investment save environment from degradation. Recently, Zhang [55] reinvestigated the finance-environment nexus and concluded that financial development increases CO_2 emissions due to inefficient allocation of financial resources to enterprises. In case of Sub Saharan African countries, Al-mulali and Sab [56] examined the dynamic relationship between energy consumption, income, financial development, and CO_2 emissions by incorporating investment and employment as potential determinants of domestic production. Their empirical exercise reported that energy consumption spurs economic growth. A rise in economic growth and energy consumption adds to the demand of financial services and hence financial development that increases the improvements in environmental quality by controlling CO_2 emissions through the implementation of well-organized and transparent financial policies. Ozturk and Acaravci [57] found that financial development does not seem to contribute in lowering CO_2 emissions in case of Turkey.

(*footnote continued*)
awareness about clean environment increases. This leads the government and people to increase their spending on environment protection and regulation. In such situation, environmental degradation and CO_2 emissions tend to decrease. This show that how EKC is an inverted-U shape i.e. an increase in income shifts the positive link between economic growth and CO_2 to zero and then goes to negative relation between the both variables (Wang [12].)

[4] Akbostanci et al. [32] did not support their findings.

The fifth strand of existing literature provides a relationship between international trade and environment. For example Grossman and Krueger [14] argued that the environmental effects of international trade depend on the policies implemented in an economy. There are two schools of thought about the impact of international trade on CO_2 emissions. The first school of thought argued that trade openness provides an offer to each country to have access to international markets which enhances the market share among countries Shahbaz et al. [36]. This leads to competition between countries and increases the efficiency of using scarce resources and encourages importing cleaner technologies in order to lower the CO_2 emissions (e.g. Runge [58]; Helpman [59]). Another group proposed that natural resources are depleted due to international trade. This depletion of natural resources raises CO_2 emissions and causes a decrease in environmental quality (e.g. [Schmalensee et al. [60]; Chaudhuri and Pfaff [62]). In country case studies, Machado [23] indicated a positive link between foreign trade and CO_2 emissions in Brazil. Mongelli et al. [24] concluded that pollution haven hypothesis exists in Italy. Halicioglu [31] added trade openness to explore the relationship between economic growth, CO_2 emissions and energy consumption in Turkey. Their results showed that trade openness are one of the main contributors to economic growth while income raises the level of CO_2 emissions. Chen [63] explored this issue in Chinese provinces and documented that industrial sector's development is linked with an increase of CO_2 emissions due to energy consumption. Nasir and Rehman [35] used ADF unit root test and cointegration test also supported EKC in Pakistan and reported positive impact of trade openness on CO_2 emissions but Shahbaz et al. [36] found that trade openness reduces CO_2 emissions. Furthermore, Tiwari et al. [38] reported that trade openness impedes environmental quality in case of India.

There are some studies available in the existing literature investigating relationship between energy consumption, economic growth and energy pollutants in case of Indonesia. For example, Masih and Masih [64] found that energy consumption is Granger caused by economic growth and the same inference was drawn by Asafu-Adjaye [65]. On contrary, Fatai et al. [66] and later on Chiou-Wei et al. [67] reported that energy consumption leads economic growth. Moreover, Soytas and Sari [68] and Ozturk and Acaravci [20] noted neutral hypothesis between energy consumption and economic growth. Jafari et al. [69] probed the relationship between energy consumption, economic growth and CO_2 emissions but incorporating capital and urbanization as potential determinants of energy consumption and energy pollutants. They noted that there is no long run relationship between the variables and urbanization Granger causes energy consumption. The empirical findings of mentioned studies are inconclusive and are not helpful to policy makers in articulating comprehensive economic, energy, financial, trade and environmental policy to sustain economic growth and hence environmental quality in case of Indonesia due to not considering financial development and trade openness while investigating the relationship between economic growth, energy consumption and CO_2 emissions. The present study is an effort to fill the gap in energy literature regarding the case study of Indonesia.

3. Modeling framework and data collection

Existing literature provides various empirical studies investigating the dynamic relationship between economic growth, energy consumption and CO_2 emissions. For instance Ang [25,26] for France and Malaysia; Soytas et al. [40] for United States; Zhang and Cheng [70], Chang [43], and Wang et al. [71] for China; Halicioglu [31] and Ozturk and Acaravci [20] for Turkey; Pao and Tsai [72] for Brazil and Alam et al. [33] for India and Bangladesh examined the causal relationship between the series. Some studies included other potential determinants of CO_2 emissions such as capital by Xepapadeas [73] and the later on by Menyah and Wolde-Rufeal [44], fossil fuel consumption by Lotfalipour et al. [74], coal consumption by Baloch et al. [75] and later on Tiwari et al. [38], electricity consumption by Lean and Smyth [19], openness and urbanization by Hossain [47], foreign direct investment by Pao et al. [22], energy intensity by Roca and AlcaHntara [76] and later on by Hatzigeorgiou et al. [77], trade openness by Nasir and Rehman [35] and later on Shahbaz et al. [36] for Pakistan.

Tamazian et al. [51] and Tamazian and Rao [52] added financial development as a potential determinant of CO_2 emissions. Later on, Yuxiang and Chen [53], Jalil and Feridun [54] and Zhang [55] investigated the empirical relationship between financial development and energy emissions. Sound and developed financial markets stimulate capitalization by attracting local and foreign investors to accelerate economic growth [78]. Financial development allocates financial resources to firms to utilize environment-friendly technology (Frankel and Rose [79]) which uses energy efficient (Sadorsky [80,81]) and emits less carbon emissions (Tamazian et al. [51]; Tamazian and Rao [52]). However, financial development harms environment by increasing CO_2 emissions through the growth of industrial sector. Following the above discussion, we investigate the relationship between economic growth, energy consumption, financial development and CO_2 emissions by incorporating trade openness. Similarly, Antweiler et al. [82] examined the impact of trade on environmental quality. They introduced composition, scale and technological effects by decomposing the trade model. Their study concluded that trade openness is beneficial to the environment if the technological effect is greater than the composition effect and scale effect. This finding shows that international trade will improve the income level of developing nations and induce them importing less polluted techniques to enhance production. Copeland and Taylor [83] supported that international trade is beneficial to environmental quality through environmental regulations and capital-labor channels. The authors documented that free trade decline CO_2 emissions because international trade will shift the production of pollution-intensive goods from developing countries to the developed nations. Managi et al. [84] found that the quality of the environment is improved if the environmental regulatory effect is stronger than the capital-labor effect. Similarly, McCarney and Adamowicz [85] suggested that trade openness improves environmental quality depending on government policies. The local government can reduce CO_2 emissions through their environmental policies. However, movement of factors of production may also move dirty industries from home countries to developing economies where laws and regulations about the environment is just a formality. For example, Feridun et al. [86] documented that trade openness harms the environmental quality in less developed economies like Nigeria. The general form of empirical equation is modeled as following:

$$C_t = f(E_t, Y_t, F_t, TR_t) \quad (1)$$

Now, we transform all the series into logarithms to attain direct elasticities. The empirical equation is modeled as follows:

$$\ln C_t = \alpha_0 + \alpha_E \ln E_t + \alpha_Y \ln Y_t + \alpha_F \ln F_t + \alpha_{TR} \ln TR_t + \mu_i \quad (2)$$

where C_t is CO_2 emissions per capita, E_t is energy consumption per capita, Y_t real GDP per capita is used as a proxy of economic growth, F_t is financial development proxied by real domestic credit to private sector per capita and TR_t represents trade openness per capita. Finally, μ_i is the error term assumed to be normally distributed with zero mean and constant variance. We presume

that rise in energy consumption will increase carbon emissions and $\alpha_E > 0$. $\alpha_Y > 0$, an increase in economic growth is linked with high CO_2 emissions otherwise $\alpha_Y < 0$. A sound financial sector may act as conduits by enabling firms in adopting advanced cleaner and environmentally friendly techniques (Talukdar and Meisner [87]) to save environment from degradation and $\alpha_F < 0$ otherwise $\alpha_F > 0$ if the focus of the financial sector is to boost industrial sector. The expected sign of trade openness is negative, $\alpha_{TR} < 0$ if production of pollutant intensive items is reduced due to the environmental protection laws. However, Grossman and Krueger [14] and Halicioglu [31] argued that the sign of α_{TR} is positive if dirty industries of developing economies are busy producing a heavy share of CO_2 emissions with their production processes.

4. Estimation strategy and data collection

4.1. Zivot–Andrews unit root test

Numerous unit root tests are available in applied economics to test the stationarity properties of the variables. These unit tests are ADF by Dickey and Fuller [88], P–P by Philips and Perron [89], KPSS by Kwiatkowski et al. [90], DF–GLS by Elliott et al. [91] and Ng–Perron by Ng and Perron [92]. These tests provide biased and spurious results due to not having information about structural break points occurred in the series. In doing so, Zivot and Andrews [1] developed three models to test the stationarity properties of the variables in the presence of a structural break point in the series: (i) this model allows a one-time change in variables at level form, (ii) this model permits a one-time change in the slope of the trend component i.e. function and (iii) model has one-time change both in intercept and the trend function of the variables to be used for empirical propose. Zivot and Andrews [1] followed three models to check the hypothesis of one-time structural break in the series as follows:

$$\Delta x_t = a + a x_{t-1} + bt + cDU_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \tag{3}$$

$$\Delta x_t = b + b x_{t-1} + ct + bDT_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \tag{4}$$

$$\Delta x_t = c + c x_{t-1} + ct + dDU_t + dDT_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \tag{5}$$

where dummy variable is indicated by DU_t showing mean shift occurred at each point with time break while trend shift variables are shown by DT_t. [5] So,

$$DU_t = \begin{cases} 1\ldots \text{if } t > TB \\ 0\ldots \text{if } t < TB \end{cases} \text{ and } DU_t = \begin{cases} t-TB\ldots \text{if } t > TB \\ 0\ldots \text{if } t < TB \end{cases}$$

The null hypothesis of unit root break date is $c=0$ which indicates that the series is not stationary with a drift not having information about structural break point while $c < 0$ hypothesis implies that the variable is found to be trend-stationary with one unknown time break. Zivot–Andrews unit root test fixes all points as potential for possible time break and provides an estimation through regression analysis for all possible break points successively. Then, this unit root test selects that time break which decreases one-sided t-statistic to test $\hat{c}(=c-1)=1$. Zivot–Andrews intimates that in the presence of end points, asymptotic distribution of the statistics is diverged to infinity point. It is necessary to choose a region where the end points of sample period are excluded. Further, we followed Zivot–Andrews suggested “trimming regions” i.e. (0.15 T, 0.85 T).

[5] We used model-5 for empirical estimations following Sen [93]).

4.2. The ARDL bounds testing cointegration approach

After testing the stationarity properties of the series, we apply the ARDL bounds testing approach developed by Pesaran et al. [94] to investigate cointegration for a long run relationship between economic growth, energy consumption, financial development, trade openness and carbon emissions for Indonesian economy. Various cointegration approaches have been applied to test the presence of cointegration between the variables in numerous studies. These approaches are Engle and Granger [95], Johansen and Juselius [96] and Phillips and Hansen [97] require that all the series should be integrated in a unique order of integration. The ARDL bounds testing approach is more appropriate as compared to other traditional cointegration approaches. For example, it seems flexible regarding the stationary properties of the variables. This approach is more suitable once variables are found to be stationary at I(1) or I(0) or I(1)/I(0). The ARDL bounds testing approach provides efficient and consistent empirical evidence for small sample data [98] as in case of Indonesia. This approach investigates short run as well as long run parameter instantaneously. The unrestricted error correction model (UECM) version of the ARDL model is expressed as follows:

$$\begin{aligned}\Delta \ln C_t = {} & \beta_1 + \beta_{DUM} DUM + \beta_C \ln C_{t-1} + \beta_E \ln E_{t-1} + \beta_Y \ln Y_{t-1} \\ & + \beta_F \ln F_{t-1} + \beta_{TR} \ln TR_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln C_{t-i} + \sum_{j=0}^{q} B_j \Delta \ln E_{t-j} \\ & + \sum_{k=0}^{r} \beta_k \Delta \ln Y_{t-k} + \sum_{l=0}^{s} \beta_l \Delta \ln F_{t-l} + \sum_{m=0}^{t} \beta_m \Delta \ln TR_{t-m} + \mu_t\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta \ln E_t = {} & \beta_1 + \beta_{DUM} DUM + \beta_C \ln C_{t-1} + \beta_E \ln E_{t-1} + \beta_Y \ln Y_{t-1} \\ & + \beta_F \ln F_{t-1} + \beta_{TR} \ln TR_{t-1} + \sum_{i=1}^{p} \phi_i \Delta \ln E_{t-i} + \sum_{j=0}^{q} \phi_j \Delta \ln C_{t-j} \\ & + \sum_{k=0}^{r} \phi_k \Delta \ln Y_{t-k} + \sum_{l=0}^{s} \phi_l \Delta \ln F_{t-l} + \sum_{m=0}^{t} \phi_m \Delta \ln F_{t-m} + \mu_t\end{aligned} \tag{7}$$

$$\begin{aligned}\Delta \ln Y_t = {} & \beta_1 + \beta_{DUM} DUM + \beta_C \ln C_{t-1} + \beta_E \ln E_{t-1} + \beta_Y \ln Y_{t-1} \\ & + \beta_F \ln F_{t-1} + \beta_{TR} \ln TR_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta \ln Y_{t-i} + \sum_{j=0}^{q} \varphi_j \Delta \ln C_{t-j} \\ & + \sum_{k=0}^{r} \varphi_k \Delta \ln E_{t-k} + \sum_{l=0}^{s} \varphi_l \Delta \ln F_{t-l} + \sum_{m=0}^{t} \varphi_m \Delta \ln F_{t-m} + \mu_t\end{aligned} \tag{8}$$

$$\begin{aligned}\Delta \ln F_t = {} & \beta_1 + \beta_{DUM} DUM + \beta_C \ln C_{t-1} + \beta_E \ln E_{t-1} + \beta_Y \ln Y_{t-1} \\ & + \beta_F \ln F_{t-1} + \beta_{TR} \ln TR_{t-1} + \sum_{i=1}^{p} \theta_i \Delta \ln F_{t-i} + \sum_{j=0}^{q} \theta_j \Delta \ln C_{t-j} \\ & + \sum_{k=0}^{r} \theta_k \Delta \ln E_{t-k} + \sum_{l=0}^{s} \theta_l \Delta \ln Y_{t-l} + \sum_{m=0}^{t} \theta_m \Delta \ln TR_{t-m} + \mu_t\end{aligned} \tag{9}$$

$$\begin{aligned}\Delta \ln TR_t = {} & \beta_1 + \beta_{DUM} DUM + \beta_C \ln C_{t-1} + \beta_E \ln E_{t-1} + \beta_Y \ln Y_{t-1} \\ & + \beta_F \ln F_{t-1} + \beta_{TR} \ln TR_{t-1} + \sum_{i=1}^{p} \theta_i \Delta \ln TR_{t-i} + \sum_{j=0}^{q} \theta_j \Delta \ln C_{t-j} \\ & + \sum_{k=0}^{r} \theta_k \Delta \ln E_{t-k} + \sum_{l=0}^{s} \theta_l \Delta \ln Y_{t-l} + \sum_{m=0}^{t} \theta_m \Delta \ln F_{t-m} + \mu_t\end{aligned} \tag{10}$$

The 1st difference operator is shown by Δ and μ_t is for residual terms. The appropriate lag length of the first difference regression is chosen on the basis of minimum value of akaike information criteria (AIC). The F-statistic is much more sensitive to lag order selection. The inappropriate lag length selection may provide misleading results. Pesaran et al. [94] developed an F-test to determine the joint significance of the coefficients of the lagged

level of the variables. For example, the hypothesis of no cointegration between the variables in Eq. (3) is H_0:$\beta_C=\beta_E=\beta_Y=\beta_F=\beta_{TR}=0$ while hypothesis of cointegration is H_a:$\beta_C\neq\beta_E\neq\beta_Y\neq\beta_F\neq\beta_{TR}\neq 0$. Pesaran et al. [94] generated two asymptotic critical values i.e. upper critical bound (UCB) and lower critical bound (LCB), are used to take decisions whether cointegration exists or not between the series. The lower critical bound is used to test cointegration if all the series are integrated at I(0) otherwise we use an upper critical bound (UCB). Our computed *F*-statistics are $F_C(C/E,Y,F,TR)$, $F_E(E/C,Y,F,TR)$, $F_Y(Y/C,E,F,TR)$, $F_F(F/C,E,Y,TR)$ and $F_{TR}(TR/C,E,Y,F)$ for Eqs. (6)–(10) correspondingly. The long run relationship between the variables exists if our calculated *F*-statistic is greater than upper critical bound (UCB). There is no cointegration between the series, if our calculated *F*-statistic does not exceed lower critical bound (LCB). Our decision regarding cointegration is inconclusive if calculated *F*-statistic falls between LCB and UCB. In such an environment, an error correction method is an easy and suitable way to investigate cointegration between the variables. We have used critical bounds generated by Narayan [99] to test cointegration rather than Pesaran et al. [94] and Turner [100].

The direction of causality between economic growth, energy consumption, financial development, trade openness and CO_2 emissions is investigated by applying the VECM Granger causality approach after confirming the presence of cointegration between the variables. On the same lines, Granger [101] argued that vector error correction method (VECM) is more appropriate to examine the causality between the series if the variables are integrated at I(1). The VECM is restricted form of unrestricted VAR (vector autoregressive) and restriction is levied on the presence of the long run relationship between the series. The system of error correction model (ECM) uses all the series endogenously. This system allows the predicted variable to explain itself both by its own lags and lags of forcing variables as-well-as the error correction term and by residual term. The VECM equations are modeled as follows:

$$(1-L)\begin{bmatrix}\ln C_t\\ \ln Y_t\\ \ln E_t\\ \ln F_t\\ \ln TR_t\end{bmatrix}=\begin{bmatrix}\varphi_1\\ \varphi_2\\ \varphi_3\\ \varphi_4\\ \varphi_5\end{bmatrix}+\sum_{i=1}^{p}(1-L)\begin{bmatrix}a_{11i}a_{12i}a_{13i}a_{14i}a_{15i}\\ b_{21i}b_{22i}b_{23i}b_{24i}b_{25i}\\ \delta_{31i}\delta_{32i}\delta_{33i}\delta_{34i}\delta_{35i}\\ \pi_{41i}\pi_{42i}\pi_{43i}\pi_{44i}\pi_{45i}\\ \theta_{51i}\theta_{52}\theta_{53i}\theta_{54i}\theta_{55i}\end{bmatrix}\times\begin{bmatrix}\ln C_{t-i}\\ \ln Y_{t-j}\\ \ln E_{t-k}\\ \ln F_{t-l}\\ \ln TR_{t-m}\end{bmatrix}+\begin{bmatrix}\beta\\ \chi\\ \xi\\ \zeta\\ \rho\end{bmatrix}ECM_{t-1}+\begin{bmatrix}\eta_{1t}\\ \eta_{2t}\\ \eta_{3t}\\ \eta_{4t}\\ \eta_{5t}\end{bmatrix} \quad (11)$$

where u_{it}, are random terms and supposed to be normally distributed with zero means and constant variances. The established long run relation between the series is further confirmed by the statistical significance of lagged error term i.e. ECT_{t-1}. The estimates of ECT_{t-1} also shows the speeds of convergence from short run towards the long run equilibrium path. The vector error correction method (VECM) is appropriate to examine causality between the variables once series are found to be cointegrated and then causality must be found at least from one direction. The VECM also distinguishes causality relationships between short-and-long runs. The VECM is also used to detect the causality in the long run, short run and joint i.e. short-and-long runs respectively.

The t-statistic of estimate of lagged error term i.e. $ECT_{t-1}$with negative sign is used to test the long run casual relation and the joint χ^2 statistical significance of the estimates of the first difference lagged independent variables is used to investigate short run causality. Economic growth Granger causes carbon emissions if $\alpha_{12,i}\neq 0\forall_i$ are founded statistically significant. On the contrary, if $\beta_{21,i}\neq 0\forall_I$ is statistically significant then causality runs from CO_2 emissions to economic growth. The rest of causal hypotheses can be inferred similarly. The joint causality i.e. long-and-short runs are investigated by using Wald or *F*-test for the joint significance of estimates of lagged terms of the independent variables and error correction term. The presence of short-and-long run causality relation between the variables is known as measure of strong Granger-causality (Shahbaz et al. [11]).

4.3. The data collection

The data on real GDP, energy consumption (kg of oil equivalent) per capita, domestic credit to the private sector as share of GDP, trade openness (exports+imports) at constant prices and CO_2 emissions (metric tons) per capita has been collected from world development indicators (CD-ROM). We have multiplied GDP series with domestic credit to the private sector as share of GDP and divided it on consumer price index (CPI) to convert it into units and real terms. Then, we have used population series to convert the series of real GDP, real domestic credit to private sector and real trade into per capita. The data sample of present study is 1975Q1–2011Q4. We used the interpolation method in Eviews-7.1 for converting the annual data of all the series into quarterly data.

5. Results and their discussions

We applied the ARDL bound testing approach to examine the long run relationship between economic growth, energy consumption, financial development, trade openness and CO_2 emissions in case of Indonesia. The advantage of bounds testing is that it is flexible regarding the order of integration of the series. This requires that the variables should be integrated at I(0) or I(1) or I(0)/I(1). The computation of the ARDL *F*-statistic becomes useless if none of the variables is stationary at I(2) or beyond that order of integration. In doing so, we have applied Zivot–Andrews structural break trended unit root test to ensure that all the variables are integrated at I(0) or I (1) or I(0)/I(1)[6]. The results of Zivot–Andrews [1]) structural break trended unit root test are reported in Table 1. Our empirical evidence discloses that all the series show unit root problem at their level but found to be integrated at I(1). This entails that the series is stationary in their first differenced form. So, unique level of the variables leads us to examine the existence of a long run relationship between economic growth, energy consumption, financial development, trade openness and CO_2 emissions by applying the ARDL bounds testing approach to cointegration in the presence of structural break in the series over the period of $1975Q_1$–$2011Q_4$.

Before applying the ARDL bounds testing, there is a prerequisite to choose the appropriate lag order of the variables to compute suitable the ARDL *F*-statistic and to test whether cointegration exists between the variables or not. The computation of *F*-test is very much sensitive to the selection of lag length (Ouattara [103]). We chose lag length 6 following minimum value of akaike information criterion (AIC). The AIC criterion has superior power properties as compared to SBC and provides effective and reliable results which help in capturing the dynamic relationship between the series (Lütkepohl [104]).[7] The next step is to apply *F*-test investigating cointegration for the long run between the variables. Table 2 reports the results of the ARDL bounds testing approach to cointegration in the presence of structural

[6] Various unit root tests are available in economics literature to examine the stationarity properties of the series. These unit root tests are ADF [88], DF-GLS [91], Ng–Perron [92], etc. These tests may provide biased and inconsistent empirical evidence regarding stationarity properties of the variables. The main reason is that ADF, DF–GLS and Ng–Perron do not seem to have information about structural breaks occurring in the time series data (Baum [102]).

[7] The results of lag order of the variables are available from authors upon request.

break in the series. The results showed that our calculated F-statistics are greater than upper critical bound at 5 per cent and 1 per cent levels, once we used CO_2 emissions, energy consumption, economic growth and trade openness are treated as predicted variables. It leads us to reject the null hypothesis of no cointegration. This indicates that there are four cointegrating vectors. This confirms that the variables are cointegrated for a long run relationship between economic growth, energy consumption, financial development, trade openness and CO_2 emissions in case of Indonesia. The structural break stems in the series of CO_2 emissions, economic growth, energy consumption and trade openness in 1993Q_1, 1997Q_4, 1989Q_3 and 1987Q_3 respectively.

After investigating the long run relationship between the variables, the next step is to examine marginal impacts of economic growth, energy consumption, financial development and trade openness on CO_2 emissions. The results are reported in Table 3 indicating that energy consumption has positive and statistically significant impact on CO_2 emissions. This shows that an increase in energy consumption contributes to energy pollutants significantly after economic growth. The results inferred that a 1 per cent rise in energy consumption is linked with a 0.6793 per cent increase in CO_2 emissions, all else the same. The relationship between economic growth and CO_2 emissions is positive and it is significant at 1 per cent level. Keeping other things same, a 1 per cent increase in economic growth raises CO_2 emissions by 0.7087 per cent. Our empirical exercise indicates that economic growth is a major contributor to CO_2 emissions in case of Indonesia.

The impact of financial development is negative and it is statistically significant at 1 per cent level of significance. It implies that a 0.2071 per cent decline in CO_2 emissions is linked with a 1 per cent increase in financial development. This exposes that financial development contributes in condensing CO_2 emissions by directing banks to provide loans to firms for those investment projects which are environmentally friendly. Trade openness is negatively linked with CO_2 emissions and it is statistically significant at 1 per cent level. This shows that trade openness provides access to developing economies of advanced technology emitting less CO_2 emissions. A 0.1665 per cent increase in CO_2 emissions can be declined by 1 per cent increase in trade openness. Furthermore, our results confirmed the presence of inverted-U shaped relationship between financial development and CO_2 emissions. The impact of linear and non-linear terms of financial development is positive and negative on CO_2 emissions and it is statistically significant at 1 per cent level. This entails that initially CO_2 emissions are positively linked with financial development and financial development starts to decline it once financial sector matures. It is suggested that the financial sector should provide loans (subsidies) for energy efficient technologies and allocate funds to energy system for exploring new sources of energy such as renewable to attain cleaner environment.

The short run results illustrated that energy consumption and economic growth have a positive impact on carbon emissions and it is statistically significant at 1 per cent level of significance. It is found that economic growth is a major contributor to carbon emissions in short run. Financial sector development is positively

Table 1
Zivot-Andrews Structural Break Trended Unit Root Test.

Variable	At level		At 1st difference	
	T-statistic	Time break	T-statistic	Time Break
$\ln C_t$	−4.714 (2)	1993Q_1	−8.554 (3)*	1982Q_4
$\ln Y_t$	−3.456 (2)	1997Q_4	−9.039 (3)*	1997Q_3
$\ln E_t$	−3.485 (1)	1989Q_3	−8.947 (2)*	1985Q_3
$\ln TR_t$	−4.796 (1)	1987Q_3	−11.624 (3)*	1988Q_4
$\ln F_t$	−4.931 (2)	1988Q_3	−6.368 (3)*	1997Q_3

Note: Lag order is shown in parenthesis.

* Significant at 1 per cent level of significance.

Table 3
Long-and-short Runs Analysis.

Dependent variable = $\ln C_t$				
Variables	Coefficient	T-statistic	Coefficient	T-statistic
Long run analysis				
Constant	−3.1364*	−11.8565	−4.4763*	−16.9071
$\ln E_t$	0.6793*	4.4001	0.5723*	4.5434
$\ln Y_t$	0.7087*	6.2678	0.8860*	9.4192
$\ln F_t$	−0.2071*	−2.1149	0.5086*	8.2468
$\ln F_t^2$	–	–	−0.0859*	−8.6552
$\ln TR_t$	−0.1665*	−3.3942	−0.1585*	−3.9780
Short run analysis				
Constant	−0.0005	−0.9757	−0.0008	−1.5194
$\ln E_t$	0.5951*	3.4510	0.6247***	1.8845
$\ln Y_t$	0.9792*	6.5648	0.9855*	4.5828
$\ln F_t$	0.0418***	1.8201	0.0372**	1.9985
$\ln F_t^2$	–	–	0.4383**	2.0576
$\ln TR_t$	−0.2269*	−6.6961	−0.1965*	−4.6752
ECM_{t-1}	−0.0660*	−2.7588	−0.0455***	−1.6650
R^2	0.6272		0.6224	
F-statistic	46.4382*		37.6449*	
Short run diagnostic tests				
Test	F-statistic	Prob. value	F-statistic	Prob. value
$\chi^2 ARCH$	2.2585	0.1351	1.4934	0.2098
$\chi^2 WHITE$	1.3646	0.1316	1.2987	0.1319
$\chi^2 REMSAY$	1.8449	0.1238	1.8959	0.1188

Note:*, ** and *** show significant at 1, 5 and 10 per cent level of significance respectively.

Table 2
The results of ARDL cointegration test.

Bounds testing to cointegration				Diagnostic tests			
Estimated models	Optimal lag length	Structural break	F-statistics	χ^2_{NORMAL}	χ^2_{ARCH}	χ^2_{RESET}	χ^2_{SERIAL}
$F_C(C/E,F,Y,TR)$	6, 6, 6, 6, 5	1993Q_1	3.737**	0.7965	[1]: 0.2802	[1]: 2.5182	[1]: 0.0101; [2]: 0.180
$F_Y(Y/C,E,F,TR)$	6, 6, 6, 6, 6	1997Q_4	3.639**	2.8024	[1]: 1.2023	[1]: 0.5162	[1]: 2.0237; [2]: 1.2909
$F_E(E/C,Y,F,TR)$	6, 6, 6, 6, 5	1989Q_3	4.893*	2.2402	[1]: 0.2038	[1]: 2.55458	[1]: 0.6995; [2]: 1.1052
$F_{TR}(TR/C,E,Y,F)$	6, 6, 5, 5, 6	1987Q_3	4.156*	0.5440	[1]: 1.1453	[1]: 0.2763	[1]: 3.1245; [2]: 1.5478
$F_F(F/C,E,Y,TR)$	6, 6, 6, 6, 6	1988Q_3	1.643	2.1622	[1]: 3.1389	[2]: 0.0750	[1]: 8.5419; [3]: 1.5834
Significant level	Critical values (T = 148) Lower bounds I(0)		Upper bounds I(1)				
1 per cent level	2.88	3.99					
5 per cent level	2.27	3.28					
10 per cent level	1.99	2.94					

Note: * and ** represents significant at 1 and 5per cent at levels respectively.

related to CO_2 emissions and significantly at 10 per cent level of significance. Trade openness is inversely related to CO_2 emissions. The linear and non-linear effect of financial development on CO_2 emissions is positive and it is statistically significant at 5 per cent level. There is no indication of inverted-U or U-shaped relationship between both variables. The statistically significant estimate of lagged error term i.e. ECM_{t-1} with negative sign corroborates our established long run relationship between economic growth, energy consumption, financial development, trade openness and carbon emissions. The empirical evidence reported in Table 3 pointed out that the coefficient of $ECM_{t-1}$is −0.0660 (−0.0455) which is statistically significant at 1(10) per cent level of significance. This concludes that changes in CO_2 emissions are corrected by 6.60 (4.55) per cent every quarter in long run.[8] It suggests that full convergence process will take three years and three quarters (five years and two quarters) reach the stable path of equilibrium. This implies that the adjustment process is very fast and significant for the Indonesian economy in any shock to a carbon emissions equation.

The empirical evidence for diagnostic tests is detailed in Table 3. The results suggest that the short run model seems to pass all tests successfully such as test autoregressive conditional heteroskedasticity, white heteroskedasticity and specification of the short run model. This indicated that there is no problem of the autoregressive conditional heteroskedasticity. The variables are homoscedastic and functional form of short run model is well organized. The show that short run empirical evidence is consistent and stable for policy purpose regarding carbon emissions in case of Indonesia.

The presence of cointegration for long run economic growth, energy consumption, financial development, trade openness and carbon emissions leads us to implement the VECM Granger causality approach to analyze the direction of causal relationship between these series. With the appropriate knowledge about the direction of causality between the variables helps policy making authorities in articulating inclusive energy, economic, financial, trade and environmental policy to sustain economic growth and improve the environmental quality over the long period of time. Granger [101] suggested that in the presence of cointegration, once variables are found to be stationary at unique order then the VECM Granger causality framework is an appropriate approach to detect the long-and-short runs causal relationship between economic growth, energy consumption, financial development, trade openness and carbon emissions. Table 4 reports the results of the Granger causality test.

In long span of time, empirical evidence indicated that the bidirectional causal relationship is found between energy consumption and CO_2 emissions. This finding is in the line of existing energy literature such as Papadopoulos and Haralambopoulos [106] and later on with Hatzigeorgiou et al. [77] in case of Greece. This implies that in current setup it is difficult for the Indonesian economy to find decoupling carbon emissions. There is a need of overhauling energy structure to encourage energy efficient technologies by considering a number of policy reforms. The feedback effect exists between economic growth and CO_2 emissions. This also suggests adopting energy efficient technology which helps in enhancing domestic production but with less CO_2 emissions. Trade openness and CO_2 emissions Granger cause each other.

The bidirectional causality is also found between economic growth and energy consumption, trade openness and economic growth and, between trade openness and energy consumption. Financial development Granger causes CO_2 emissions, energy consumption, economic growth and trade openness.

The unidirectional causality is found running from financial development to carbon emissions. This supports the argument that financial development lowers CO_2 emissions by encouraging the firms to adopt advanced technology which emits less carbon emissions during production. These results are consistent with energy literature such as Talukdar and Meisner [87]. Energy consumption is Granger caused by financial development is consistent with view explored by Shahbaz and Lean [5] that sound financial sector enables the firms to adopt advance and energy efficient technology during production process. The supply-side hypothesis is validated as analysis showed that economic growth and trade openness are Granger cause of financial development.

In short span of time, causality analysis unveiled that energy consumption and energy consumption are Granger cause each other (Solie [107]). The bidirectional causality is found between economic growth and CO_2 emissions and the same inference can be drawn for CO_2 emissions and trade openness. The feedback hypothesis also exists between economic growth and CO_2 emissions. The unidirectional causality is found running from economic growth to financial development. Financial development Granger causes trade openness. The joint long-and-short runs causality analysis also supports the empirical findings for long run as well as short run.

It is argued in economic literature that the Granger causality approaches such as the VECM Granger causality test has some limitations. The causality test cannot capture the relative strength of causal relation between the variables beyond the selected time period. This weakens the reliability of causality results by the VECM Granger approach. To solve this issue, we applied innovative accounting approach (IAA) i.e. variance decomposition method and impulse response function. We have implemented the generalized forecast error variance decomposition method using vector autoregressive (VAR) system to test the strength of causal relationship between economic growth, energy consumption, financial development, trade openness and CO_2 emissions in case of Indonesia. The variance decomposition approach indicates the magnitude of the predicted error variance for a series accounted for by innovations from each of the independent variable over different time-horizons beyond the selected time period. It is pointed by Pesaran and Shin [108] that the generalized forecast error variance decomposition method shows proportional contribution in one variable due to innovative shocks stemming in other variables. The main advantage of this approach is that like orthogonalized forecast error variance decomposition approach; it is insensitive with ordering of the variables because ordering of the variables is uniquely determined by VAR system. Further, the generalized forecast error variance decomposition approach estimates the simultaneous shock affects. Engle and Granger [95] and Ibrahim [109] argued that with VAR framework, variance decomposition approach produces better results as compared to other traditional approaches.

The results of variance decomposition approach are described in Table 5. The empirical evidence indicates that a 46.13 per cent portion of CO_2 emissions is contributed by its own innovative shocks and one standard deviation shock in energy consumption explains energy pollutants by 20.23 per cent. Economic growth contributes to CO_2 emissions by 19.36 per cent due to one standard shock stemming in economic growth. This contribution in CO_2 emissions due to economic growth first rises, goes to peak point, and then starts to fall. This confirms the existence of inverted-U shaped relationship between economic growth and CO_2 emissions in case of Indonesia. The share of financial development and trade openness in CO_2 emissions is very minimal i.e. 3.11 and 8.68 per cent respectively.

[8] The statistically significance of lagged error term i.e. ECM_{t-1} is a further proof of the existence of stable long run relationship between the series (Banerjee et al. [105]).

Table 4
The VECM Granger causality analysis.

Dependent variable	Direction of causality										
	Short run					Long run	Joint long-and-short run causality				
	$\Delta \ln C_{t-1}$	$\Delta \ln E_{t-1}$	$\Delta \ln Y_{t-1}$	$\Delta \ln F_{t-1}$	$\Delta \ln TR_{t-1}$	ECT_{t-1}	$\Delta \ln C_{t-1}, ECT_{t-1}$	$\Delta \ln E_{t-1}, ECT_{t-1}$	$\Delta \ln Y_{t-1}, ECT_{t-1}$	$\Delta \ln F_{t-1}, ECT_{t-1}$	$\Delta \ln TR_{t-1}, ECT_{t-1}$
$\Delta \ln C_t$	–	8.6546* [0.0003]	26.2339* [0.0000]	0.1984 [0.8203]	20.7217* [0.0000]	−0.0641* [−3.7242]	–	12.6546* [0.0000]	21.6459* [0.0000]	5.1929* [0.0020]	18.9303* [0.0000]
$\Delta \ln E_t$	12.2848* [0.0000]	–	0.5176 [0.5969]	1.2592 [0.2872]	0.5732 [0.5650]	−0.0344*** [−1.8653]	8.5510* [0.0000]	–	2.4968*** [0.0625]	2.9509** [0.0525]	2.0405*** [0.1011]
$\Delta \ln Y_t$	23.4326* [0.0000]	0.7469 [0.4757]	–	0.6856 [0.5055]	0.3237 [0.7240]	−0.0332** [−2.4718]	18.1810 [0.0000]	2.2994*** [0.0802]	–	2.2019*** [0.0907]	3.4320** [0.0189]
$\Delta \ln F_t$	1.8417 [0.1624]	1.2551 [0.2883]	3.6708** [0.0280]	–	4.2191** [0.0167]	–	–	–	–	–	–
$\Delta \ln TR_t$	20.3999* [0.0000]	0.1615 [0.8510]	0.8530 [0.4284]	17.2249* [0.0000]	–	−0.1062* [−4.1462]	20.3190* [0.0000]	6.2682* [0.0005]	5.8402* [0.0009]	21.4440* [0.0000]	–

Note: *, ** and *** show significance at 1, 5 and 10 per cent levels respectively.

The contribution of CO_2 emissions, economic growth, financial development and trade openness to energy consumption is 2.5179, 11.7488, 0.3158 and 9.3970 per cent while rest is explained by innovative shocks of energy consumption itself. One standard shock in economic growth explains 54.46 per cent itself. CO_2 emissions contribute to economic growth by 14.55 per cent and share of energy consumption to economic growth is 11.05 per cent. Economic growth is 19.87 per cent explained by one standard shock stemming in trade openness.

A 7.85 (4.55) per cent portion of financial development (energy consumption) is explained by one standard deviation shock in CO_2 emissions (energy consumption) and 11.59 per cent portion is contributed to financial development by its own innovative shocks. A standard deviation shock stemming in economic growth and trade openness attribute to financial development by 53.46 and 22.53 per cent respectively. One standard shock stemming in CO_2 emissions and energy consumption explain economic growth by 17.08 and 22.43 per cent respectively. The share of economic growth and financial development to contribute in trade openness is negligible i.e. 3.73 and 2.32 per cent and, a 54.41 per cent portion of trade openness is contributed by its own standard shocks.

The impulse response function is alternate of variance decomposition approach and shows the reaction in one variable due to shocks stemming in other variables. Fig. 1 indicated the positive response in carbon emissions due to standard shocks stemming in energy consumption. The CO_2 emissions is inverted U-shaped responded by economic growth. This implies that CO_2 emissions rise, go to peak and then start to fall with continues economic growth. The response in CO_2 emissions is negative by shocks stemming in financial development. This means that financial development contributes in condensing carbon emissions. The contribution of trade openness to CO_2 emissions is negative. This implies that trade openness is environment friendly.

The response in energy consumption first rises then goes down and becomes negative due shocks stemming in carbon emissions. The contribution of economic growth is positive to energy consumption while response of energy consumption is depleting first then becomes positive due to standard shock in financial development. Trade openness improves environmental quality as response in CO_2 emissions following standard shocks occurring in trade openness. CO_2 emissions and energy consumption attribute economic growth positive but trade openness contributes negatively to economic growth. The impact of financial development on economic growth is undetermined. Energy consumption and economic growth contribute to financial development due to innovative shocks in both variables. A standard shock occurs in trade openness reduces financial development. The response in trade openness is fluctuating due to standard shock in CO_2 emissions and same inference is drawn for economic growth and trade openness. Energy consumption contributes to trade openness and impact is increasing with passage of time.

6. Conclusion and future directions

This study investigated the dynamic relationship between economic growth, energy consumption, financial development, trade openness and CO_2 emissions in case of Indonesian economy over the period of $1975Q_1$–$2011Q_4$. For this purpose, we applied the ARDL bounds testing approach to cointegration to examine the cointegration among the variables in the presence of structural breaks in series for long run. The VECM Granger causality is applied to test the direction of causal relationship between the variables and robustness of causality analysis was tested by using innovative accounting approach (IAA).

Our results indicated that the variables are cointegrated for long run relationship in the presence of structural breaks in the series. The empirical evidence showed that energy consumption increases carbon emissions and economic growth is a major contributor to CO_2 emissions. Financial development condenses carbon emissions and inverted-U shaped relationship is also confirmed between financial development and carbon emissions. This validates the contribution of financial sector to improve the quality of environment. Trade openness also declines energy pollutants. The causality analysis exposed the bidirectional causality between energy consumption and carbon emissions. Economic growth and carbon emissions are interrelated. Feedback hypothesis is validated between CO_2 emissions and trade openness. Energy consumption and economic growth Granger cause each other. Financial development Granger causes energy consumption, energy pollutants, economic growth and trade openness.

Our results imply that carbon emissions can be reduced at the cost of economic growth or energy efficient technologies should be encouraged to enhance domestic production with the help of financial sector and import environment friendly technology from advanced countries. Financial development Granger causes energy consumption which reveals that adoption of energy conservation policy would not adversely affect economic growth. Again, financial sector must fix its focus on the allocation of funds to those firms which adopt environment friendly technologies and encourage the firms to use more energy efficient technology for production purpose and hence to save environment from degradation.

Table 5
Variance decomposition approach.

Period	S.E.	$\ln C_t$	$\ln E_t$	$\ln Y_t$	$\ln F_t$	$\ln TR_t$
Variance decomposition of $\ln C_t$						
1	0.0047	100.0000	0.0000	0.0000	0.0000	0.0000
2	0.0083	98.4467	0.0069	0.8214	0.2541	0.4706
3	0.0117	95.8616	0.0058	2.5727	0.4253	1.1343
4	0.0150	92.4785	0.0057	5.1277	0.4952	1.8926
5	0.0166	87.7277	0.0626	7.95206	1.3501	2.9073
6	0.0177	82.8780	0.3653	11.0311	2.0655	3.6599
7	0.0186	77.4637	1.1938	14.2044	2.7760	4.3620
8	0.0194	71.7384	2.8087	16.9597	3.4690	5.0239
9	0.0202	66.4171	5.3386	19.0870	3.4830	5.6741
10	0.0211	61.3777	8.4017	20.2444	3.4088	6.5671
11	0.0219	57.0433	11.5831	20.5077	3.2716	7.5933
12	0.0226	53.4903	14.5400	20.1671	3.1161	8.6863
13	0.0232	50.5062	16.8910	19.7573	3.0307	9.8146
14	0.0238	48.1259	18.7645	19.3683	2.9627	10.7784
15	0.0243	46.1344	20.2357	19.1181	2.9063	11.6052
Variance decomposition of $\ln E_t$						
1	0.0017	17.4031	82.5968	0.0000	0.0000	0.0000
2	0.0031	14.4025	85.1169	0.2188	0.0144	0.2471
3	0.0046	11.7134	86.8747	0.7850	0.0132	0.6135
4	0.0062	9.3627	87.9545	1.6257	0.0074	1.0495
5	0.0073	6.9611	88.0054	3.4013	0.0154	1.6166
6	0.0082	5.4918	87.2236	5.2245	0.0122	2.0477
7	0.0090	4.7468	85.6814	7.0326	0.0126	2.5264
8	0.0097	4.5354	83.6185	8.7406	0.0174	3.0878
9	0.0105	4.0189	82.5120	9.6000	0.0745	3.7944
10	0.0112	3.6029	81.3141	10.1827	0.1293	4.7708
11	0.0120	3.2371	80.2796	10.4541	0.1869	5.8420
12	0.0127	2.9079	79.4237	10.4946	0.2479	6.9257
13	0.0134	2.7606	78.2502	10.8086	0.2673	7.9131
14	0.0140	2.6311	77.1846	11.1828	0.2917	8.7095
15	0.0146	2.5179	76.0203	11.7488	0.3158	9.3970
Variance decomposition of $\ln Y_t$						
1	0.0020	40.6418	2.0541	57.3039	0.0000	0.0000
2	0.0038	36.2332	2.0890	61.4500	6.37E-05	0.2276
3	0.0059	33.0522	2.3100	63.9148	0.0205	0.7023
4	0.0082	30.4170	2.6485	65.4592	0.0706	1.4045
5	0.0098	27.5972	2.8743	66.6821	0.0506	2.7956
6	0.0112	25.0908	3.2657	67.1881	0.0430	4.4121
7	0.0126	22.8585	3.7461	67.0481	0.0510	6.2960
8	0.0138	20.9235	4.2840	66.2997	0.0796	8.4129
9	0.0149	19.2754	5.2263	65.1770	0.0746	10.2465
10	0.0160	17.9561	6.2898	63.5758	0.0693	12.1088
11	0.0170	16.8824	7.4824	61.6820	0.0637	13.8893
12	0.0179	15.9970	8.7633	59.6560	0.0583	15.5252
13	0.0189	15.3942	9.7224	57.6800	0.0541	17.1492
14	0.0197	14.9038	10.5105	55.9342	0.0515	18.5997
15	0.0206	14.5514	11.0596	54.4609	0.0489	19.8790
Variance decomposition of $\ln F_t$						
1	0.0059	1.1567	11.2437	8.4014	79.1980	0.0000
2	0.0105	0.9544	12.0715	10.8954	75.9501	0.1283
3	0.0150	0.8772	13.0946	13.6162	71.7450	0.6667
4	0.0195	0.8227	14.0305	16.2981	67.1847	1.6638
5	0.0261	5.9223	10.1966	28.5080	51.3398	4.0331
6	0.0344	9.7685	6.9243	39.1114	37.5832	6.6123
7	0.0440	11.9677	4.7259	46.5925	27.9646	8.74914
8	0.0547	13.0699	3.3448	51.5876	21.5329	10.4646
9	0.0627	12.1871	2.8673	54.1394	18.2418	12.5642
10	0.0697	11.2075	2.7349	55.4966	16.0829	14.4778
11	0.0756	10.2505	2.8610	55.9800	14.5582	16.3501
12	0.0806	9.3929	3.1932	55.7807	13.4307	18.2024
13	0.0855	8.7377	3.6396	55.2794	12.6388	19.7043
14	0.0899	8.2304	4.1114	54.4529	12.0380	21.1671
15	0.0939	7.8551	4.5531	53.4620	11.5940	22.5356
Variance decomposition of $\ln TR_t$						
1	0.0069	23.2645	4.2113	0.0021	1.3486	71.1732
2	0.0131	23.3914	3.9679	0.6290	0.7487	71.2628
3	0.0194	23.4065	4.0717	2.0348	0.6501	69.8366
4	0.0257	23.3723	4.3120	4.1325	0.7081	67.4748
5	0.0283	20.1512	4.9515	4.7049	0.6974	69.4947
6	0.0297	18.3687	5.7157	4.8374	0.8374	70.2406
7	0.0304	17.8343	6.5153	4.7206	1.2939	69.6357
8	0.0309	18.4338	7.2447	4.5835	2.2497	67.4881

Table 5 (*continued*)

Period	S.E.	$\ln C_t$	$\ln E_t$	$\ln Y_t$	$\ln F_t$	$\ln TR_t$
9	0.0311	18.1932	8.2638	4.5216	2.3062	66.7149
10	0.0314	17.9355	9.5590	4.4553	2.3417	65.7082
11	0.0317	17.7919	11.275	4.3690	2.2983	64.2651
12	0.0323	17.9238	13.4355	4.2390	2.2342	62.1673
13	0.0329	17.6609	16.2504	4.0879	2.2455	59.7551
14	0.0337	17.3787	19.3690	3.9074	2.2519	57.0928
15	0.0345	17.0875	22.4373	3.7351	2.3280	54.4118

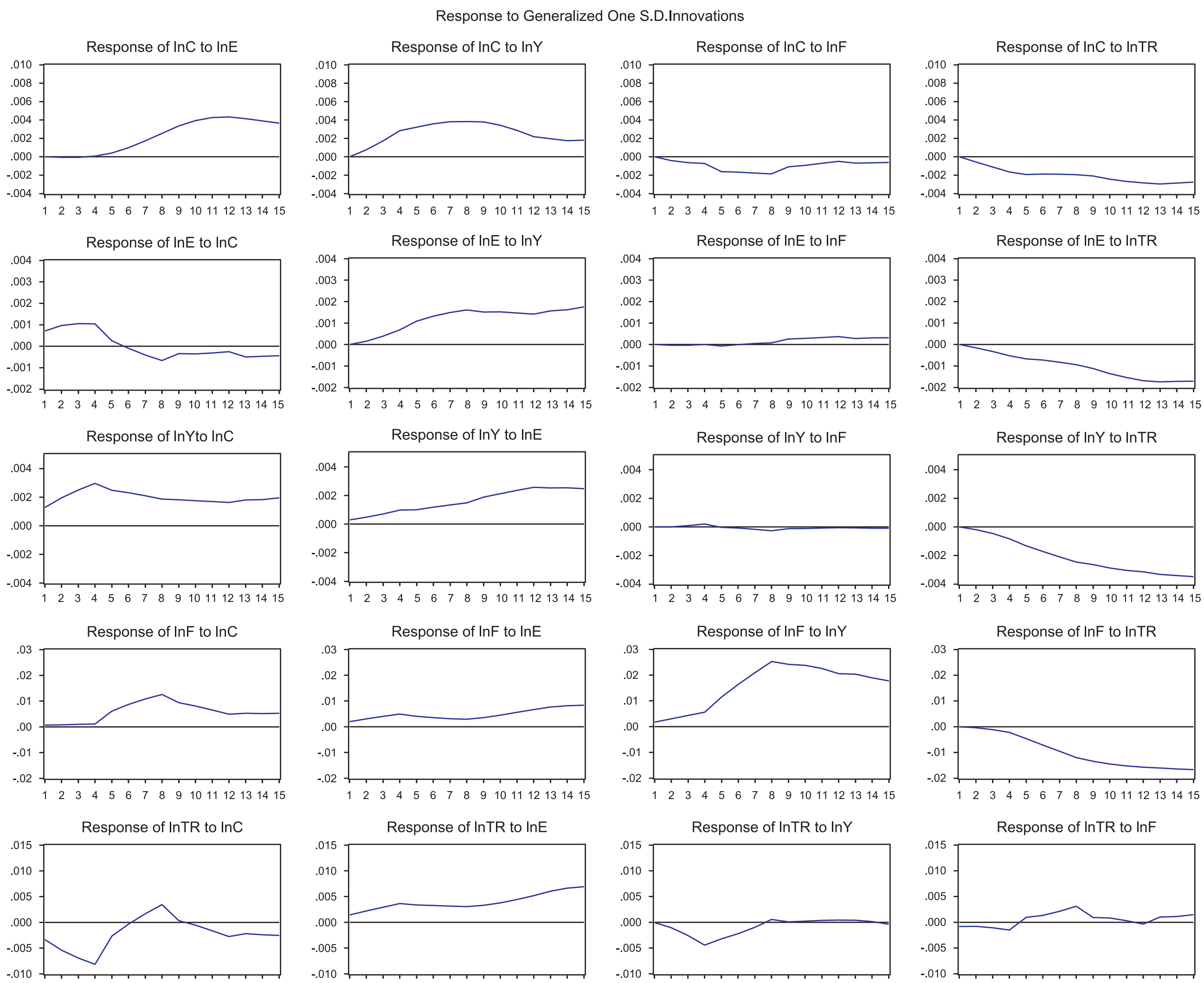


Fig. 1. Impulse response function.

The rising trend of carbon emissions in current momentum is a debatable issue in case of Indonesia. To overcome this controversial issue, there is a need of comprehensive economic, financial and energy policy reforms to sustain economic growth by developing domestic financial sector. The present study can be augmented for future research by investigating the relationship between renewable energy consumption, nonrenewable energy consumption, economic growth and carbon emissions following (Tiwari [110,111]; Shahbaz et al. [36]). Other variables may also be included in model as potential determinants of carbon emissions such as urbanization (Hossain [47]); foreign direct investment (Pao and Tsai [112]); exchange rate/terms of trade (Jalil and Feridun [54]); interest rate (Karanfil [113]); population or population density (Himayatullah et al. [114]) and industrialization (Zhang [55]) to examine relationship between economic growth, energy intensity and CO_2 emissions in case of Indonesia.

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